Initiation and funding

The work is supported by the Norwegian University of Science and Technology. My supervisors are Erling Ildstad and Rolf Hegerberg. I started this work in May 1994 and the thesis is due by May 1999.

Introduction

Measurements of dielectric response either in time or frequency domain has shown to be a promising method for detecting water treeing in XLPE power cables. By performing a single measurement of the dielectric response, the average degree of degradation can be obtained. This is not sufficient, as electric breakdown is closer related to the length of the longest water tree than to the density or the degree of generalised ageing.

However, it is experimentally shown that in case of long water trees the dielectric response increase more than proportional with increasing test voltage above a certain voltage level. This nonlinearity of the dielectric response is found to be sensitive to localized water tree ageing in XLPE cables.

Measurements in frequency domain have shown to be successful in order to detect vented water trees which is considered the most detrimental upon service life of MV XLPE cables.

However, the effect of vented water trees upon the time domain dielectric response has previously not been found to give a clear-cut nonlinearity. In these investigations the nonlinearity was assigned to the presence of bow-tie trees.

In this paper this is experimentally investigated by performing time and frequency domain measure-

Figure 1. Schematic representation of the different parts of the XLPE Rogowski type test object. The NaCl particles are inserted on the upper semiconductive screen in order to accelerate the water tree ageing. b) Typical vented water trees after 20 weeks of ageing.
ments on laboratory vented water tree aged Rogowski samples.

**Examples of experimental results**

The accelerated water treeing ageing test has been performed by using the Rogowski test object schematically shown in Figure 1. A total of 50 samples were manufactured from quality crosslinked low density polyethylene (XLPE). The semiconductive screens were used as high voltage and ground electrodes, and the aluminium backing serves as an electric contact and a water tight barrier, preventing water from evaporating from the lower semiconductor (the ground electrode) during the water tree ageing. In order to accelerate vented water tree ageing, 200 0.2ml water droplets contaminated with 0.1M NaCl, were placed on the upper semiconductive screen on each object by using a microliter-syringe.

As can be seen in Figure 1b), large vented water trees typically grow from the upper semiconductive screens, and only few and small grows from the lower screen. The largest vented water trees found in each sample typically penetrated 60-70% of the insulation wall after 20 weeks of ageing. Only few and small bow-tie trees were detected.

The effect of vented water treeing is found to increase the time domain dielectric response nonlinearly as a function of the applied voltage. In Figure 2a), the currents after 20s is plotted as a function of the applied voltage. In case of the non-treed sample, the currents follows linearly the charging voltages up to 6 kV (4.6kV/mm). The water treed sample aged for 20 weeks displays however a strong nonlinearity, thus the response is linear at lower voltages up to approximately 1.5kV (1.2kV/mm), and becomes nonlinear at higher voltage levels.

The frequency domain dielectric response also becomes nonlinear when vented water trees are present. The nonlinearity is specially high after 20 weeks of ageing. However, after 12 weeks of ageing, the response saturates at approximately 1.5kV, and from this voltage level becomes linear.

Thus both methods can detect vented water treeing in XLPE insulation, indicated by a nonlinear increase of the responses.

Figure 2. a) Typically depolarisation currents measured on unaged and water tree aged Rogowski samples (1.3mm in thickness) as a function of charging voltages up to 6kV (4.6kV/mm). The effect of water treeing is to increase the magnitude of the currents and the degree of nonlinearity.

b) Measured dielectric loss factor, $\varepsilon''$, as a function of applied voltages at 0.1Hz. at different ageing times. The effect of ageing is to increase the responses in magnitudes as well as to become nonlinear.

All applied voltages are peak values.